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Lifetime Maximization in Wireless Sensor Networks using Tabu Swarm Optimization

M.Dhivya[a], M.Sundarambal[b],a*

[a]Department of EEE, Anna University of Technology Coimbatore, Coimbatore,TamilNadu-641047,India
[b]Department of EEE, Coimbatore of Technology, Coimbatore,TamilNadu-641014,India

Abstract

Wireless sensor networks (WSNs) consist of autonomous nodes for monitoring an environment. Several concerns in sensor networks are formulated as multidimensional optimization problems, and approximated through computational intelligence techniques. Routing in Sensor Networks is based on energy optimization and Quality of Service. In this paper a static clustered architecture is developed for energy efficient routing in Sensor Networks using a new version of swarm intelligence namely Tabu Swarm Optimization comprising Particle Swarm Optimization and Tabu Search. The Hybrid approach is efficiently utilized to minimize the energy consumption and prolong the lifetime of distributed sensor network. The results obtained are compared with the previous techniques, to validate ease of computation. Extensive experimental results show that the proposed approach is efficient in clustering, energy minimization, and lifetime.

Keywords: Wireless Sensor Networks, routing, energy efficiency, Particle Swarm Optimization, Tabu Search, Meta-heuristics, Tabu Swarm Optimization (TSO)

1. Introduction

Wireless sensor networks (WSNs) facilitate innovative applications and necessitate non-conventional paradigms for protocol design. Sensor node is a tiny device that includes three basic components: a sensing subsystem for data acquisition from the physical surrounding environment, a processing

* M.Dhivya. Tel.: +91 8148361129;
E-mail address: dhivyamanian@gmail.com.

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subsystem for local data processing and storage, and a wireless communication subsystem for data transmission [1]. The diversity benefit of achieving reliable communication at a much lower transmission energy cost is very desirable in energy constrained , resource-constrained wireless sensor networks [2]. Traditional routing protocols for Sensor Networks are Directed Diffusion, Flooding and Gossiping, Sensor Protocols for Information via negotiation (SPIN), Rumor Routing, Gradient Based Routing (GBR), COUGAR, Low Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient Gathering in Sensor Information Systems (PEGASIS), Threshold sensitive Energy Efficient sensor Network protocol (TEEN), Geographic Adaptive Fidelity (GAF),SPEED,etc.

In recent years, extensive reviews of the general energy aware routing research are provided [1, 3, and 4]. From the previous literature it is inferred that, the traditional routing and cluster based routing approaches lacks in meeting real time requirements, dynamic topology change, mobility, and computation time. The previous approaches has constraints in selecting shortest path which might not be a minimum energy cost route, decreasing the energy consumption by replacing the hop-count routing with minimum energy routing and unpredictable node deaths. Hence parallel solution methods and evolutionary techniques are more preferred for computation. In some duality models the network's optimization problem can be solved by a primal Parallel algorithm for fixed rates and a dual parallel algorithm for shadow prices or congestion signals and energy optimization [5].

The significance of Computational Intelligence techniques had led them in the application of dynamic optimization problems like data aggregation and fusion, energy aware routing, task scheduling, security, optimal deployment and localization in Wireless Sensor Networks [6]. In this paper, a metaheuristic approach incorporating Particle Swarm Optimization (PSO) and Tabu Search (TS) is used for energy aware routing in Wireless Sensor Networks. The Hybrid approach is implemented to get enhanced network performance by compensating the deficiency of one algorithm with another. Initially the clusters are formed by calculating the distance between the nodes and residual energy. Once the clusters are formed, the intercluster routing is done through TSO. The Tabu Swarm approach incorporates the features of both the PSO and TS algorithms. The advantages and disadvantages of both approaches are balanced and an efficient routing technique is formulated.

The rest of the article is as follows. Theoretical Background is discussed in section 2. The proposed methodology is discussed in section 3. Experimental results and development of the simulation environment using MATLAB are summarized in section 4 and Section 5 draws conclusions.

2. Statement of the Problem

The simplified energy model widely used in sensor networks is LEACH traffic model. Among the other models, the LEACH hierarchical [7] model merited extensive attention in the context of cluster based routing protocols with its distributed cluster formation and randomized rotation of cluster-heads. Most of the clustering algorithms developed in the past decade, used the assumptions and considerations of LEACH in design of energy model with regard to any practical application. The following are the most widely used assumptions and model in sensor network simulation and analysis.

All nodes remain stationary and are initially charged with some base energy. Multi-hop situation is allowed for better communication link. Nodes can be arranged randomly in the two dimensional space. Constraints required for the base station from the nodes are neglected when the base station is located away from the network area.GPS devices which are used to sense the network nodes are neglected. Noise interference, signal fading and other losses are neglected during communication linkage. The distance between the ‘n’ sensors from the base station from the point P (x_i, y_i) is given in (1).

$$d(i, j) = (x_i - x_n)^2 + (y_i - y_n)^2 \tag{1}$$

$$E_{TX} = \{l.Electrical + \varepsilon_{fs}.d^{2}\left(for\ 0 \le d \le d_{crossover}\right) \quad (2)$$

(Or)

$$E_{TX} = \{l.Electrical + \varepsilon_{mp}.d^{4}\left(ford \ge d_{crossover}\right) \quad (3)$$

The amount of energy consumed for transmission E_{Tx}, of *l*-bit message over a distance d is given in (2) and (3). Electrical is the amount of energy consumed in electronic circuits, ε_{fs} is the energy consumed in an amplifier when transmitting at a distance shorter than $d_{crossover,}$ and ε_{mp} is the energy consumed in an amplifier when transmitting at a distance greater than $d_{crossover}$.

3. Proposed Routing Methodology

3.1 Cluster Formation:

A clustering algorithm attempts to find natural groups of components (or data) based on some similarity. Also, the clustering algorithm finds the centroid of a group of data sets. Generally, the distance between two points is taken as a common metric to assess the similarity among the components of a population. The commonly used distance measure is the Euclidean metric which defines the distance between two points d (x_i, y_i) is given in equation (1).

The Cluster Head (CH) is formed considering the residual energy, distance to the base station and the distance to the nearby nodes. Once the Cluster Head is formed, the cluster members are elected by advertising the CH s node ID, residual energy and distance to the base station. The non Cluster Head node joins a particular Cluster by acknowledging a message with node ID, Residual energy and the ID of the CH to join with. After the clusters are formed, the Cluster Heads (CHs) fuse or aggregate the information before forwarding it to the base station. The inter cluster and intra cluster routing via shortest path is to be performed based on the application. For intra cluster communication, the most widely used methodology as followed by the basic LEACH algorithm concept is TDMA Scheduling- Time Division Multiple Access Scheduling is followed.

3.2 Methodology of Hybrid Algorithm:

The energy function for the Tabu Swarm Optimization is designed as in equation (4);

$$f(df\ i) = \sum_{i=1}^{n-1}\left(100\ * d\ i\right) \quad (4)$$

The above equation is derived from equation (2/3), by considering the value of ε_{mp} as 100 pJ/bit/m^2 for n=2, i.e.; communication range between the sensors. The fitness function *F*, is considered in this problem for minimization of energy and maximization of lifetime of the nodes.

For inter cluster communication, Hybrid optimization encompassing Tabu Swarm Optimization is used. In case of PSO, when a particle discovers a good solution, other particles gather around the solution global best. Therefore they cannot escape from a local optimal solution. Consequently, Swarm Optimization cannot achieve global solution. The new algorithm is based on PSO by getting hints from the concept of TS. In the search process of Tabu Swarm, the best solution at the present i.e., local best and global best which are obtained in the search are updated on two possibilities (or) groups of particles namely, ***Local Swarm*** which plays the role of local searches, and the other is ***Global Swarm*** *which* plays the role of global searches. It is based on shinichi nakona model [8] of considering two groups of swarms. These two swarms can search efficiently for the solution space.

- By this movement, particles have the possibilities of discovering the better solution different from the solution at the present i.e., Tabu Swarm can achieve operations of escalation in solution by the action of these two kind of swarms.
- The particle adjusts its position based on the individual experience and the swarm's intelligence**.** The global best is calculated using PSO. The particle that gives global best is set as the initial solution for tabu search. Subset of neighbours are generated and evaluated to find the best solution. To expedite the convergence speed, the particles are further updated using the tabu search method before entering the next iteration. The Sample Combination for Tabu Swarm Optimization is given in Figure 2.

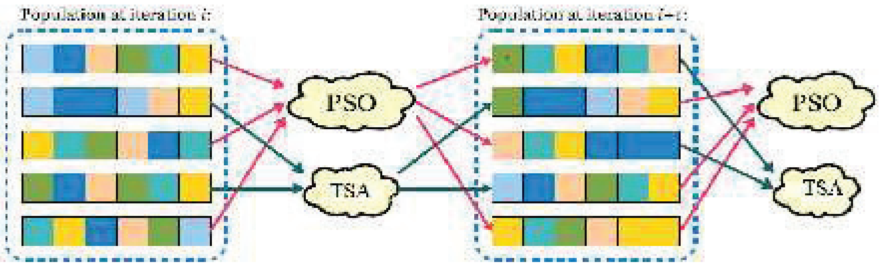

Fig 1: Sample Combination for Tabu Swarm Optimization

4. Experimental Results

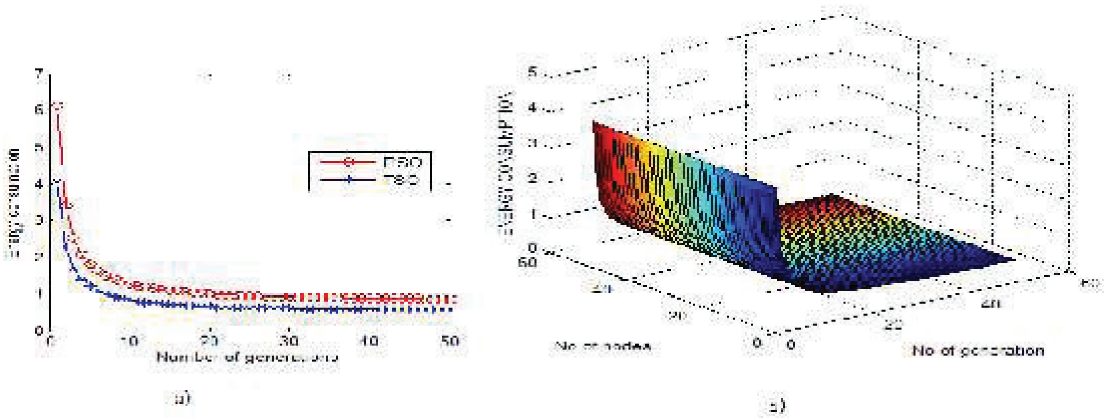

Fig 2: a) Energy consumption Vs Number of generations
b) 3D view of energy consumption for TSO.

In Figure 2 a), the average cost of energy consumption is given in contrast with Particle Swarm Optimization and Tabu Swarm Optimization. On increasing the simulation runs, relatively there will be a better performance in the proposed method. This indicates that TSO is more stable than PSO and provides better convergence. The initial energy of the net is 0.5 joules i.e., 500milli joules (mj). There are two reasons leading to minimal energy consumption by the Tabu Swarm Optimization algorithm:

- First is, the algorithm uses clustering concept which makes the communication block turn off when no data is transferred from the nodes in this block.
- Secondly, the optimum routing between the cluster-heads and the Sink reduce the data transfer cost.

Meanwhile, both the energy of nodes and the communication cost of nodes are considered which balance the energy load of the network, this characteristic is showed in Figure 2 a. In Figure 2b, the surface plot for Energy consumption of nodes is analysed with respect to number of iterations/generations, number of nodes and energy. About 12% improvement on energy consumption is achieved from TSO when compared with conventional Particle Swarm Optimization.Table1 explains the amount of data transmitted to the base station when the node is exhausted of energy.

Table 1: Percentage of Node Deaths

Base Station	Protocol	First Node Die	50% Node Die	100% Node Die
[0,0]	PSO	14207	15646	15980
	TSO	19793	18290	17328
[50,50]	PSO	14257	14560	15407
	TSO	19219	17743	16159

5. Conclusion

In this paper a cluster based optimization incorporating Tabu Search and PSO for multi-hop WSNs is proposed. The Tabu Swarm Optimization synthesized the intuitionist advantages of Tabu Search and optimal search capability of Particle Swarm Optimization. The minimum energy consumed by a Wireless Sensor Network is determined by evaluating the optimum number of cluster head nodes at each level. The limitation of this article is, it is implemented for static network configuration. It is worthy to research in the future, the realistic environment with a hardware implementation in FPGA or VLSI. Future research will encompass the application of proposed TSO for solving Swarm intelligence techniques combined with cross-layer design and Parameter learning.

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